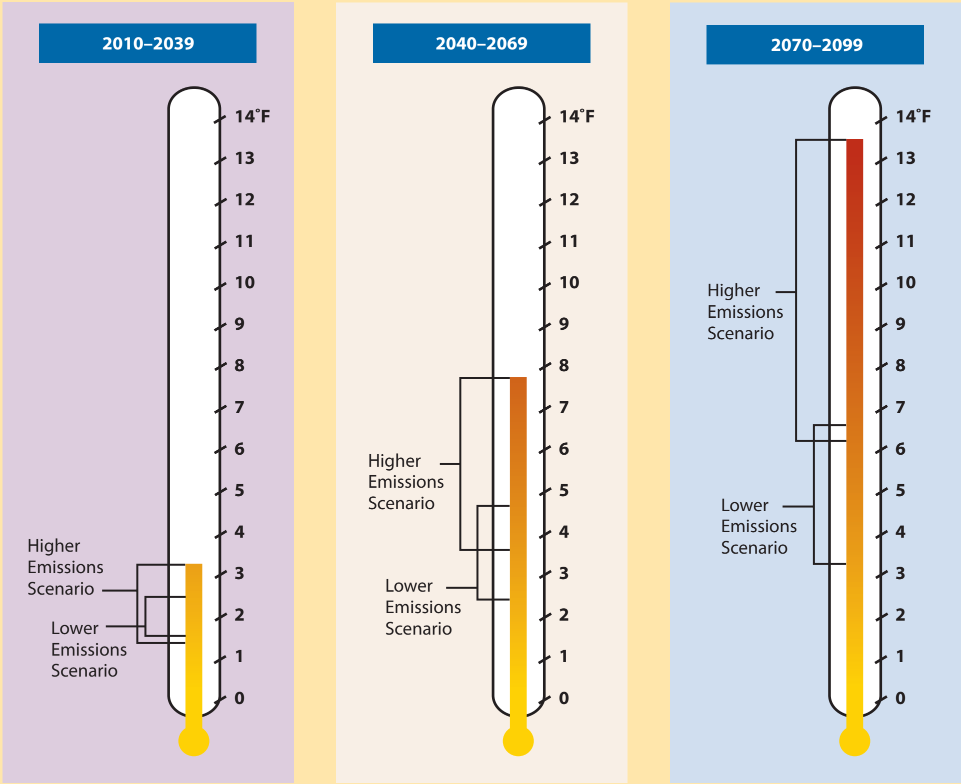
The Changing Northeast Climate

OUR CHOICES, OUR LEGACY

Across the Northeast, from Pennsylvania and New Jersey northward to Maine, signs of our rapidly changing climate become clearer each year. Records show that spring is arriving sooner, summers are growing hotter, and winters are becoming warmer and less snowy. These changes are consistent with global warming, an increasingly urgent phenomenon driven by heat-trapping emissions from human activities. New state-of-the-art climate research shows that if global warming emissions continue to grow unabated, the Northeast can expect dramatic temperature increases and other climate changes over the course of this century. If the rate of emissions is lowered, however, projections show the changes will be significantly smaller. Emissions choices we make today—in the Northeast and worldwide—will help determine the climate our children and grandchildren inherit, and shape the consequences for their economy, environment, and quality of life.

FIGURE 1: **Changes in Regional Average Summer Temperature**



The Northeast is already experiencing rising temperatures, with dramatic warming expected later this century if our heat-trapping emissions continue to increase unabated. How high temperatures rise depends on the emissions choices we make next, in the Northeast and globally. These thermometers show projected increases in regional average summer temperatures for three time periods: early-, mid-, and late-twenty-first century. Temperature ranges reflect the results of three different state-of-the-art climate models.

Photos at left: © Associated Press, except skier (© Jodi Hilton).

The nine states clustered in the northeastern corner of the United States form a diverse region famous for its bustling urban centers and quaint historic towns, peaks and pastoral landscapes, rocky shores and sand beaches. The character of the region is also defined by its distinct climate. A striking seasonal cycle punctuated by extreme events such as ice storms, floods, and nor'easters helps shape daily life. Within each season, the region is famous for weather that changes rapidly from one day (or even hour) to the next, and from year to year, average conditions can vary widely. However, the general climate patterns of the Northeast have remained fairly consistent since Europeans first landed on our shores. Lifestyles, communities, and the regional economy—to say nothing of the region's vital ecosystems—are accustomed to these conditions and the annual promenade through the seasons. In recent decades, however, the characteristic climate of the region has begun to change beyond what we have experienced in previous centuries.

The Northeast's climate is now changing rapidly. Patterns familiar to residents since recordkeeping began, including the arrival of the seasons, duration of snow cover, and timing of lake and river ice breakup, have been broken and new trends have begun to emerge. The average temperature, for instance, rose gradually over much of the twentieth century, then at an accelerated pace in recent decades, with winter temperatures rising 3.8 degrees Fahrenheit (°F) between 1970 and 2000. With this rate of change, winter conditions familiar to residents of Massachusetts, for example, during most of the twentieth century have been replaced in the last several decades by a winter climate more typical of Pennsylvania.

> If global warming emissions continue to grow unabated, the Northeast can expect dramatic temperature increases over the course of this century.

These regional changes are part of the broader global warming trend. Today, virtually all scientists agree that the planet is warming and that this warming is driven by increasing levels of heat-trapping emissions (primarily carbon dioxide) from human activities such as the burning of coal, oil, and natural gas to generate electricity and fuel our cars.

According to new peer-reviewed research conducted with state-of-the-art climate models, the Northeast should brace for significant additional change, from higher temperatures and shifting seasons to reduced snow cover and increases in extreme weather. How large these changes will be, and how different our future climate may be from the one we know,

Associated Press

People living in urban areas, especially children, the elderly, and the poor, are most vulnerable to rising heat.

depends on emissions choices we make now and in the near term, both regionally and globally.

The research summarized here provides detailed projections of what the Northeast's climate might look like during the twenty-first century following two different emissions scenarios or "pathways." One possible future is a climate driven by continued high emissions—a future where we remain heavily reliant on fossil fuels, causing heat-trapping emissions to rise rapidly over the course of the century. Another possible future is a climate driven by lower levels of emissions—a future in which we shift away from fossil fuels in favor of clean energy technologies, resulting in declining emissions by mid-century.

New projections show that climate changes already under way will continue to accelerate on both the higher- and lower-emissions pathways. However, these two pathways lead to starkly different climate futures. The higher-emissions pathway could result in dramatic regional warming of 7 to 12°F on average by the end of the century, while lower emissions would cause roughly half this warming. To put these projections into perspective, average global temperatures during the last ice age (when the location of present-day New York City was under a mile of ice) were 6 to 9°F cooler than today. If we follow our current higher-emissions pathway, the typical summer in upstate New York may feel like the present-

By the end of the century, the typical summer in upstate New York may feel like the present-day summer in South Carolina.

day summer in South Carolina by the end of the century, while summers in New Hampshire could feel like the current summer climate of North Carolina.

A walk through the seasonal cycle below explores the implications of climate change for the Northeast in more detail.

Summer

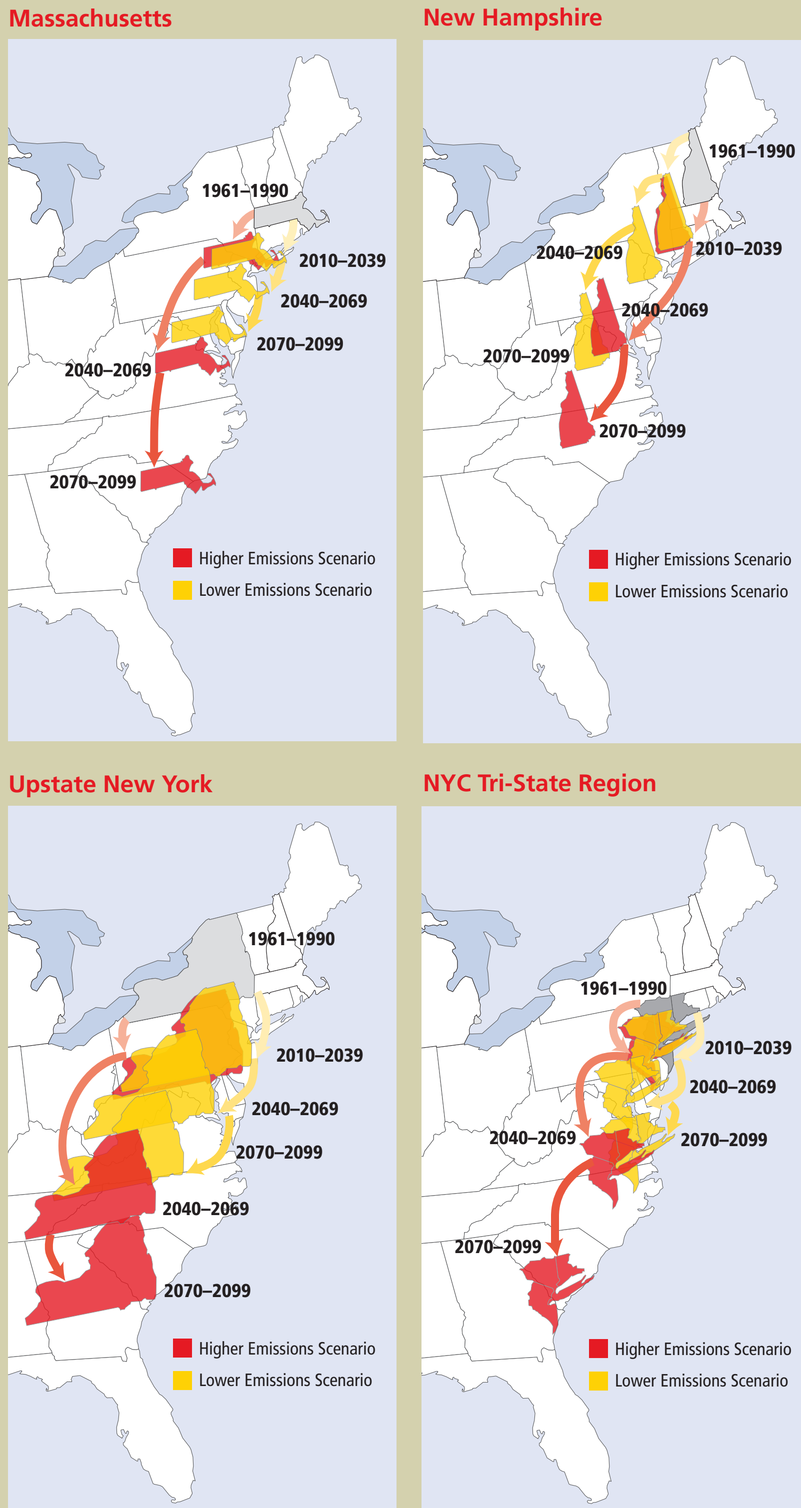

Associated Press

The typical northeastern summer is characterized by warm, often humid days. Summers tend to bring heat waves of several successive days over 90°F and, in much of the region, the occasional sweltering day above 100°F, when inhabitants seek cool relief at the beach, the air-conditioned office, the public pool, or the movie theater.

The typical summer, though, has already begun to change, with average summer temperatures rising roughly 1°F across the region since 1970 and the number of extremely hot days increasing slightly. Over the next few decades (2010 to 2039), increases in summer temperatures from 1 to 3°F are expected on both the lower- and higher-emissions pathways because of heat-trapping emissions already released into the atmosphere. By mid-century (2040 to 2069), the significance of the emissions choices we make today will become clearer, with higher emissions leading to distinctly hotter summer temperatures (Figure 1). In the latter part of the century (2070 to 2099), higher emissions lead to summer temperature increases between 6 and nearly 14°F—double the increase projected for the lower-emissions pathway.

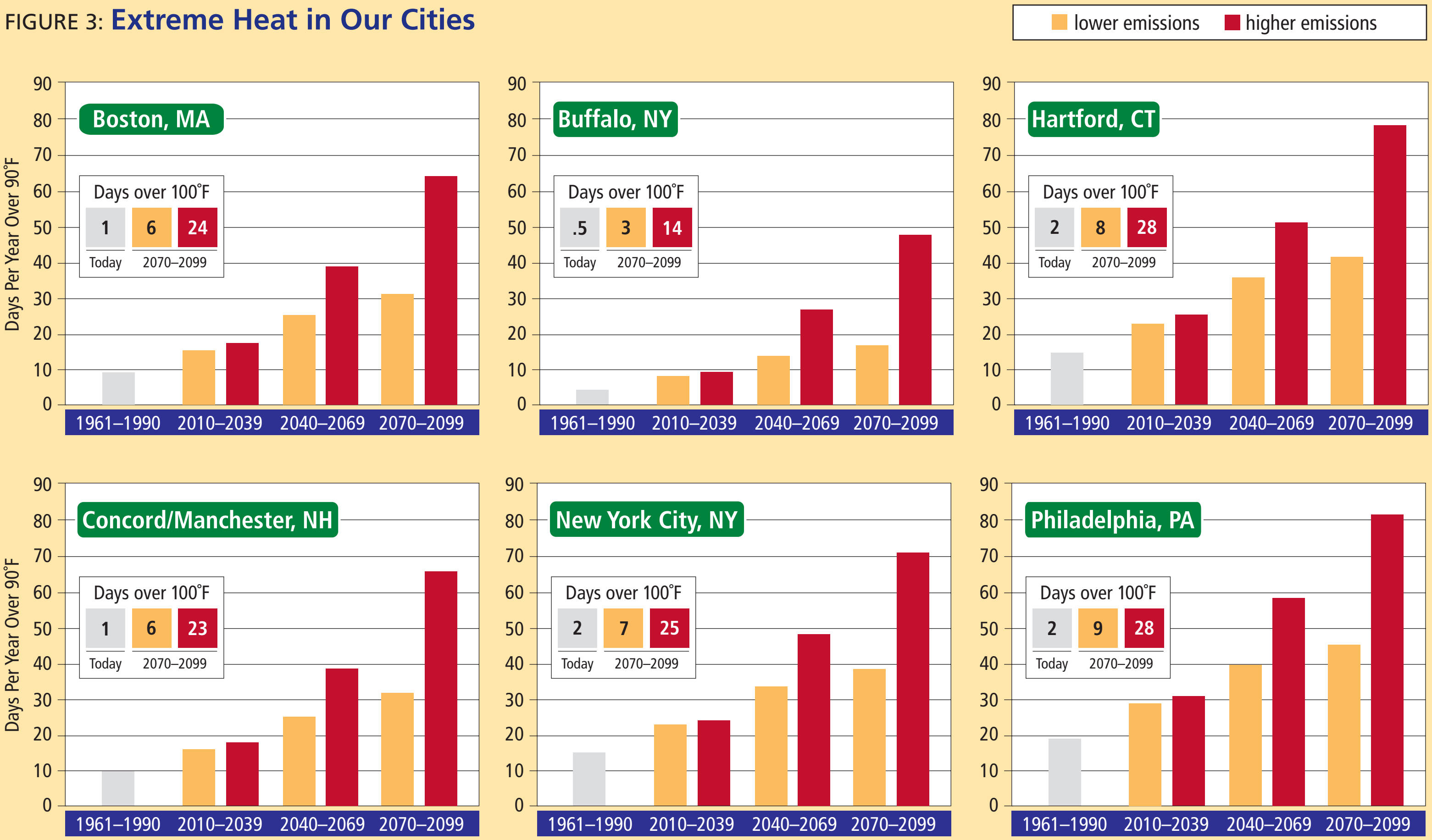
Heat index. Heat index, which combines temperature and humidity to capture how hot weather conditions actually feel, provides a useful measure of summer climate in the region. Thus, on a day when the thermometer reads 80°F, conditions can feel even warmer depending on the amount of

FIGURE 2: **Migrating State Climates**



Changes in average summer heat index will strongly alter how summer feels to residents of the Northeast. Red arrows track what summers in, for example, the NYC Tri-State Region (the greater New York City metropolitan region, encompassing parts of New Jersey and Connecticut) could feel like over the course of the century if we follow a higher-emissions pathway. Yellow arrows track what states could feel like on a lower-emissions pathway, demonstrating that our emissions choices make a difference.

FIGURE 3: Extreme Heat in Our Cities



Nearly 14 million people live in the bustling urban centers of the Northeast—and everyone feels the heat when summer temperatures soar into the 90s. Amplified by the urban heat island effect, the number of days over 90˚F is projected to increase over the course of the century until, by the end of the century, some cities could experience nearly an entire summer of above 90˚F daytime heat. Projections also show a dramatic increase in the currently small number of blistering days over 100°F (shown in boxes). The good news is that reducing our emissions today will help lower the number of dangerously hot days significantly. Projections represent the average of three climate models.

humidity in the air. Over the course of the century, as the air warms and is able to hold more moisture, rising summer temperatures across the region are likely to be amplified by rising humidity. With higher emissions, summer days in some states may feel as much as 20°F warmer than today. In contrast, the lower-emissions pathway produces significantly smaller increases. Changes in specific state climates, measured in average summer heat index, are illustrated in Figure 2.

Extreme heat. While summer heat affects us all, extreme heat is a particular concern in big cities. Hot temperatures intensified by the urban heat island effect can create dangerous conditions, especially for the elderly, infants, the poor, and other vulnerable populations. With higher global warming emissions, projections show dramatic increases in the number of days over both 90 and 100°F. By mid-century, the large northeastern cities shown in Figure 3 are expected to experience a tripling in the number of days over 90°F. In the latter part of the century, most of these cities could experience more than 60 days per year with temperatures topping 90°F, and some cities as many as 80 days. With lower emissions, roughly half this increase is expected. These cities currently endure, at most, two days of 100°F weather in the average summer. With higher emissions, all but one of these cities are projected to experience more than 20 such days each year by the end of the century. By contrast, these cities would experience around six days per year at this extreme with lower emissions.

These projections show that conditions dangerous to human health could become commonplace in most of the region's major urban centers over the course of this century. In a region where 25 percent of the population resides in urban areas, the difference that lower global warming emissions could make becomes clear. Though temperatures rise on either emissions pathway, lower emissions would create significantly smaller increases in extreme heat.

In addition, the summer season is likely to expand in the Northeast, with characteristic summer weather arriving three weeks earlier in the spring and extending three weeks later into the fall if we follow the higher-emissions pathway. For many in the Northeast, longer summers might appear at first to be a positive change. But summers defined by the oppressive heat projected for the region clearly pose difficult challenges. How will these temperatures affect daily life in the region? How will the health of vulnerable groups such as the elderly, the very young, and the poor be affected by extreme heat? How readily can people adapt by, for example, outfitting older housing stock with adequate air conditioning? How will our energy infrastructure cope with a major increase in demand for cooling? While the Northeast will need to face these questions on some level regardless of its choice of emissions, a future climate driven by higher emissions poses starkly greater challenges.

Fall


Rick McKenzie

Perhaps more than any other season, fall captures the unique character of the Northeast, ushering in brisk days, iconic harvests, brightly colored landscapes, and flocks of tourists. From an ecological perspective, fall is an important transition period. Its cooling temperatures and shortened days send a signal to many plant and animal species to prepare for the dormant winter months; in trees, these changes help produce the vibrant colors of the region's fall foliage. With higher global warming emissions, projections for the fall months show increasing temperatures and a three-week delay in the arrival of typical cool fall weather toward the end of the century. The effects will likely be felt across the landscape, e.g., in our ecosystems, by agriculture, and by the tourism industry.

> Most major Northeast cities currently experience no more than two days of 100°F weather in the average summer, but on a higher-emissions pathway that number could rise to more than 20 days.

Fall is also a time when streamflow in northeastern waterways is typically replenished. Many rivers and streams in the region experience periods of reduced flow during the summer, creating low water levels and putting stress on fish and other aquatic creatures. During the fall, streamflow increases and conditions improve. With higher emissions, however, projections show that stressfully low water levels could occur nearly a month earlier in the summer and persist almost a month longer into the fall. The low-flow period is expected to expand with lower emissions as well, by roughly two additional weeks in fall. As the frequency of extremely low, even dry, riverbeds increases in the fall months, the stress for plants and wildlife dependent on the return of normal fall streamflow also increases.

Increasing Drought in the Northeast

From Pennsylvania north to New York and Vermont and eastward to Maine, the Northeast is known for rolling green hills and lush pastures. It is not commonly associated with drought, but periods of short (one- to three-month) seasonal droughts do affect much of the region once every two or three years on average. Longer droughts (more than three months) are currently infrequent, affecting parts of the region only once every 20 or 30 years.

On a higher-emissions pathway, a short seasonal drought can be expected every year in most of New England by the end of this century, while the frequency of longer droughts could triple to once every 6 to 10 years in parts of New York, Pennsylvania, and Maine—the region's key agricultural states. On a lower-emissions pathway, the risk of drought is projected to be only slightly greater than today. Drought creates increased competition for limited water resources, agricultural crop damage, ecosystem stress, and risk of wildfire.


Melissa Laser, Maine Atlantic Salmon Commission

Scientists monitor low water levels in Maine's Sheepscot River during a three-year drought. Survival rates for fish such as salmon and trout diminish when water levels in rivers and streams are dangerously low.

A brief recurrence of warm summer days during the fall months is fondly welcomed as "Indian summer" by many in the region. But the projections outlined here do not describe a pleasant, extended summer season. Instead, they suggest the continuing encroachment of hot, dry summer days into the historically cool time of fall, creating conditions outside the experience of people and ecosystems in the Northeast.

Winter

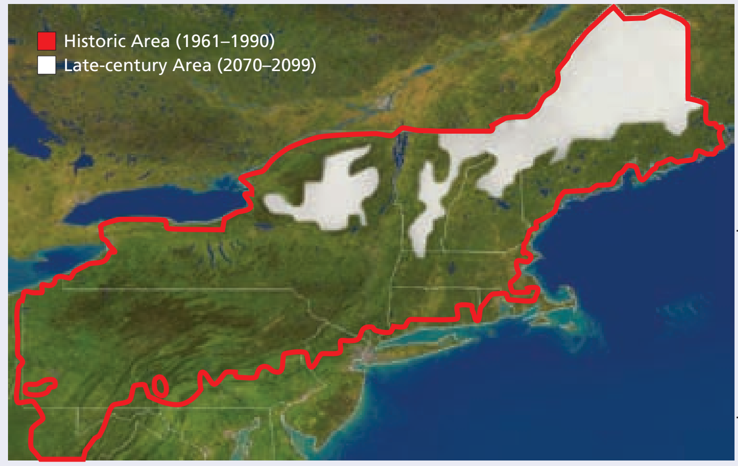
Communities in the Northeast brace for change with the approach of winter. Entire warm-weather industries close down and cold-weather operations, from skiing to snow removal, roll into action. People contend with snow, ice, and the deep chill of winter in various ways, from retreating indoors to embracing winter recreation. Despite the occasional hard winter, though, winter has softened its grip on the region in recent years. Since 1970, winter temperatures have already increased at an average rate of 1.3°F per decade, and measurable changes such as reduced snow cover and lake ice duration have occurred across the winter landscape.

In the next few decades, further winter warming of 2.5 to 4°F is expected across the region. By mid-century, higher global warming emissions drive greater temperature increases—between 4 and 7°F warmer, as compared with 3.5 to 5°F warmer under lower emissions. By the end of the century, between 8 and 12°F of winter warming can be expected with higher emissions; increases between 5 and 7.5°F are expected with lower emissions.

> By the latter part of this century, higher emissions will cut by half the number of snow-covered days across most of the region.

Warmer winter temperatures can mean less natural snow cover, and many in the Northeast have already recognized such a trend. Records from the mid-twentieth century through 2000 show that the number of snow-covered days across the Northeast has decreased significantly. Less precipitation has fallen as snow and warmer temperatures have melted the snow more quickly. At the same time, the snow on the ground has become wetter and heavier (more "slushy") on average. Winter precipitation in the future is likely to increase, with the potential for slightly greater increases on the higher-emissions pathway. However, this is unlikely to mean more white winters but rather more winter rain.

FIGURE 4: **The Changing Face of Winter**



Base map Intraresearch d.b.a. MapMart

On a higher-emissions pathway, far less of the Northeast will experience a typical snow season toward the end of the century. The red line in this map captures the area of the northeastern United States that, historically, has at least a dusting of snow on the ground for at least 30 days in the average year. The white area shows the projected retreat of this snow cover by century's end, suggesting a significant change in the Northeast's winter character.

Of course, snow cover is far from uniform across the Northeast. In Pennsylvania, the number of days with at least a dusting of snow on the ground is typically between 20 and 45 per year, whereas certain parts of northern New York, Vermont, New Hampshire, and Maine are under snow cover nearly the entire winter. Over the course of this century, the number of snow-covered days is projected to decline in all of the northeastern states. If we follow the higher-emissions pathway, the northern part of the region can expect half the typical number of snow-covered days by late in the century—fundamentally changing the winter landscape and threatening winter recreation opportunities (especially where artificial snow making is not an option). By contrast, lower emissions would result in a 25 percent reduction in snow-covered days. Thus, while some winter warming and reduced snowfall appears inevitable, the most extreme change is not.

Spring

As winter turns to spring, the Northeast welcomes the arrival of mild weather and a landscape reawakening to life. The blooming of certain flowers, the budding of leaves on trees, the disappearance of snow from the ground and ice from lakes and rivers, and the return of robins are all regional hallmarks of winter's end. Across the Northeast, changes in these indicators over the past several decades suggest that spring is already arriving sooner. For example, the dates on which the

In Rochester, NH, heavy rains flooded the Axe Handle Brook, leading to this bridge collapse. Extensive flooding in May 2006 in south and central New Hampshire resulted in millions of dollars in damage and disaster aid to residents. Global warming is expected to increase the occurrence and severity of extreme precipitation in the Northeast.

Associated Press

first blooms typically appear on lilacs, honeysuckle, and other well-known species are four to eight days earlier than in the 1960s. Long-term records for the northern part of the region also show lake ice melting an average of nine days earlier and river ice breaking up an average of 11 days sooner than the twentieth century average.

In the coming years, many indicators of spring are expected to arrive even earlier, tracking the rise in temperatures during the late winter and spring months. Measured by the dates on which the first leaves and blooms typically appear on various species, spring is projected to start two days earlier each decade if we follow the higher-emissions pathway, meaning that spring will arrive almost three weeks earlier by the end of this century. On the lower-emissions pathway, the changes are not as dramatic, culminating in a one- to two-week early arrival.

Spring will not only arrive earlier, but also likely end sooner. By the end of the century, higher emissions may cause hot summer conditions to arrive more than three weeks earlier than today.

Ecologically, spring means plant growth and animal migration and mating, with the life cycles of many plant and animal species closely synchronized. Significant changes in temperature can disrupt these relationships. The early emergence of leaves and insects, for instance, can pose significant challenges to insect-eating bird species whose northward migration is timed according to the length of the day rather than temperature. In the future, by the time these birds arrive in the Northeast, their main food source (insects) may have already peaked in number, driven by higher spring temperatures, and may not be abundant enough to support them.

Spring precipitation is an integral part of the season, as the saying "April showers bring May flowers" suggests, but extreme precipitation can cause tremendous damage and disruption to our ecosystems, homes, businesses, and public infrastructure. Though extreme precipitation can occur in any season, heavy rains in spring can be compounded by snowmelt, runoff, and seasonally high water levels in rivers, sometimes resulting in severe flooding. Measurable increases in the number of storms producing heavy rainfall have already occurred across the Northeast in recent decades, and both average and extreme precipitation are expected to continue to increase. While extreme precipitation can be measured in many ways, each of the commonly used definitions shows future increases in the frequency of these events. Similar increases are expected on both the lower- and higher-emissions pathways.

Sea-Level Rise

As global temperatures continue to rise, the oceans are warming and expanding while ice sheets and glaciers are melting more rapidly, causing increased amounts of fresh water to flow into the sea. The net result is global sea-level rise, which has regional implications. As oceans rise, the risk of permanent inundation of low-lying coastal land increases. At the same time, the risk of major wave and flood damage resulting from coastal storms raging on top of rising seas also increases.

On the higher-emissions pathway, both global sea level and sea level in the Northeast are expected to rise between eight inches and three feet by the end of the century. However, there is considerable uncertainty about the stability of some of the planet's major ice sheets. It is possible that heat-trapping emissions and the resulting temperature increases in this century will exceed the threshold beyond which we can no longer prevent the complete meltdown of the massive Greenland and West Antarctic ice sheets. Such rapid disintegrations of major ice sheets have occurred in the past, but our scientific models are currently unable to predict them. Collapse of the Greenland and West Antarctic ice sheets could cause global sea level to rise more than 20 feet over several centuries. The emissions choices we make today may therefore determine whether—or when—this critical threshold is crossed.

Choices and Solutions

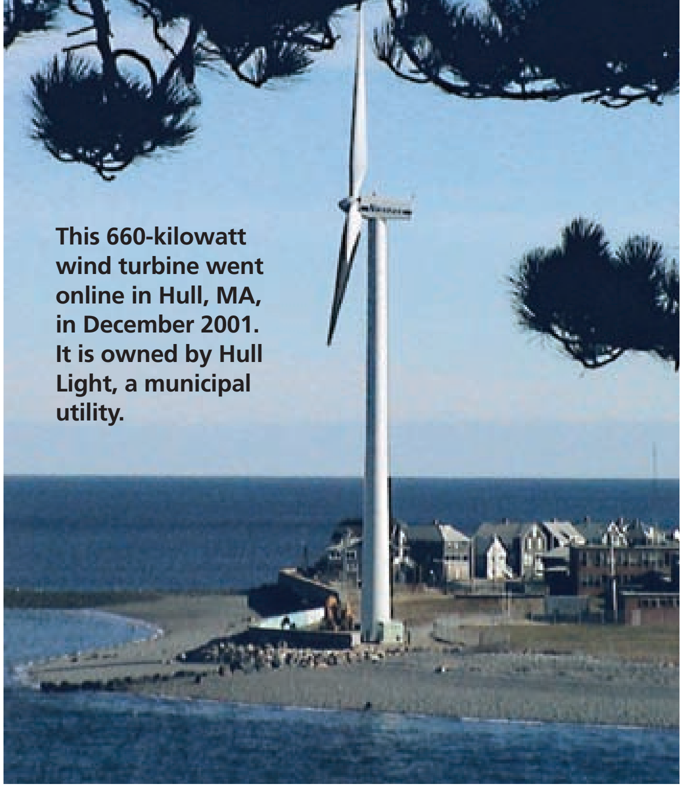
The emissions pathways available to us in the Northeast and around the globe lead to sharply contrasting climate futures. The choices we make today and in the coming years matter greatly; they have the potential to help preserve—or fundamentally change—the natural, economic, and social character of the Northeast. With leadership, innovation, and commitment behind the actions we take, lower emissions levels than those discussed here may be within our reach. Without strong action, however, we could experience emissions levels as high or higher than those described here.

Since climate change is driven by global emissions, choices made in the Northeast alone will not determine which climate future comes to pass. But as a global leader in technology, finance, and innovation, and as a major source of carbon dioxide emissions, the Northeast is well positioned to spur global progress with committed climate action. Individuals, communities, businesses, and policy makers who choose to pursue the complementary strategies outlined below can help shape the climate our children and grandchildren will inherit.

Reducing heat-trapping emissions. The most important and urgent step to curbing global warming and limiting the consequences for our climate is reducing heat-trapping emissions. The Northeast can achieve needed emissions cuts and build on its legacy of environmental leadership by continuing to increase industrial and building efficiency, switching to renewable energy sources such as wind and bioenergy, and driving more efficient vehicles. These strategies not only reduce emissions but also typically yield significant economic savings as well as health and environmental benefits.

> By reducing our emissions now, we can prevent the more severe consequences of global warming and ensure a more promising future for our children and grandchildren.

One of the most promising options in the near term is the full implementation of a strong "cap-and-trade" program for heat-trapping emissions. Here again, northeastern states have exhibited national leadership by joining together in a cooperative effort to reduce carbon dioxide emissions from power plants. This type of flexible program harnesses the efficiency of the marketplace to achieve emissions reductions in the most cost-effective manner. In the 1990s, the cap-and-trade approach proved successful at rapidly reducing acid rain pollution affecting the Northeast. Now, with strong follow-through by the states involved, the Northeast's current effort can serve again as a national model for federal policy.



This 660-kilowatt wind turbine went online in Hull, MA, in December 2001. It is owned by Hull Light, a municipal utility.

Doug Welch

Coping with the consequences of climate change that cannot be avoided. Preparing for unavoidable climate change is a necessary complement to emissions cuts, requiring careful integration of climate risks into both near- and long-term management strategies. For example, by improving community intervention programs that provide assistance during dangerous heat waves, we can reduce the health risks to the most vulnerable populations. By minimizing pressures on the environment that worsen the impact of climate change, we can help sensitive ecosystems maintain their ability to cope with a changing climate.

Because global warming is already upon us and some amount of additional warming is inevitable, the Northeast must prepare to cope with certain changes in our climate. However, by reducing our emissions now, we can prevent the more severe consequences and ensure a promising future for our children and the generations to come.

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This summary was prepared by the Union of Concerned Scientists based on *Climate Change in the U.S. Northeast*, a report of the Northeast Climate Impacts Assessment (NECIA, 2006), and on two studies by K. Hayhoe, C. Wake, and collaborators on the NECIA Climate Team: "Past and future changes in climate and hydrological indicators in the U.S. Northeast" (published in *Climate Dynamics*) and "Quantifying the regional impacts of global climate change" (in review at the *Bulletin of the American Meteorological Society*). The NECIA is a collaboration between the Union of Concerned Scientists and a team of independent experts to assess the effects of global warming in the Northeast United States.

For more information on our changing Northeast climate or to download a copy of the report *Climate Change in the U.S. Northeast*, visit *www.climatechoices.org*.

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